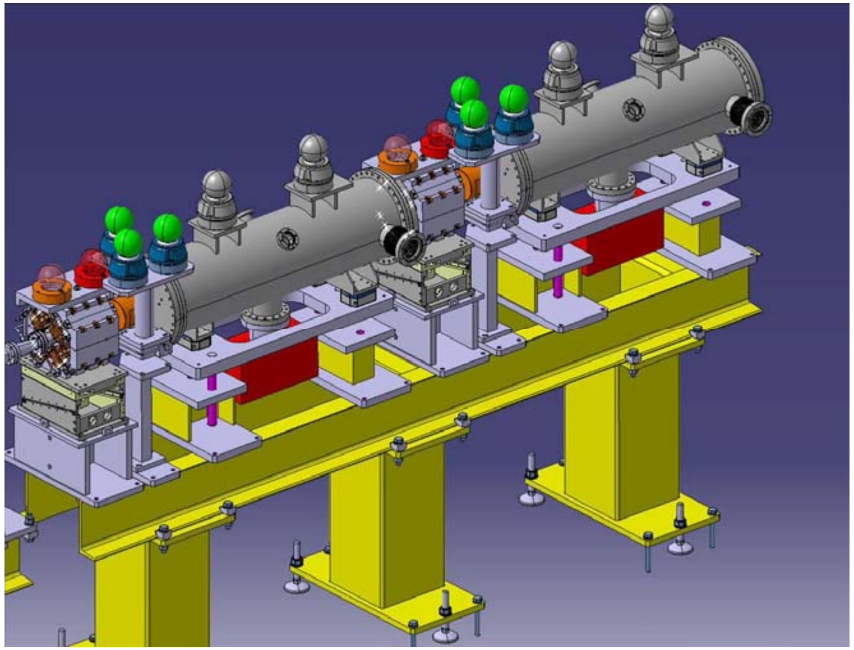
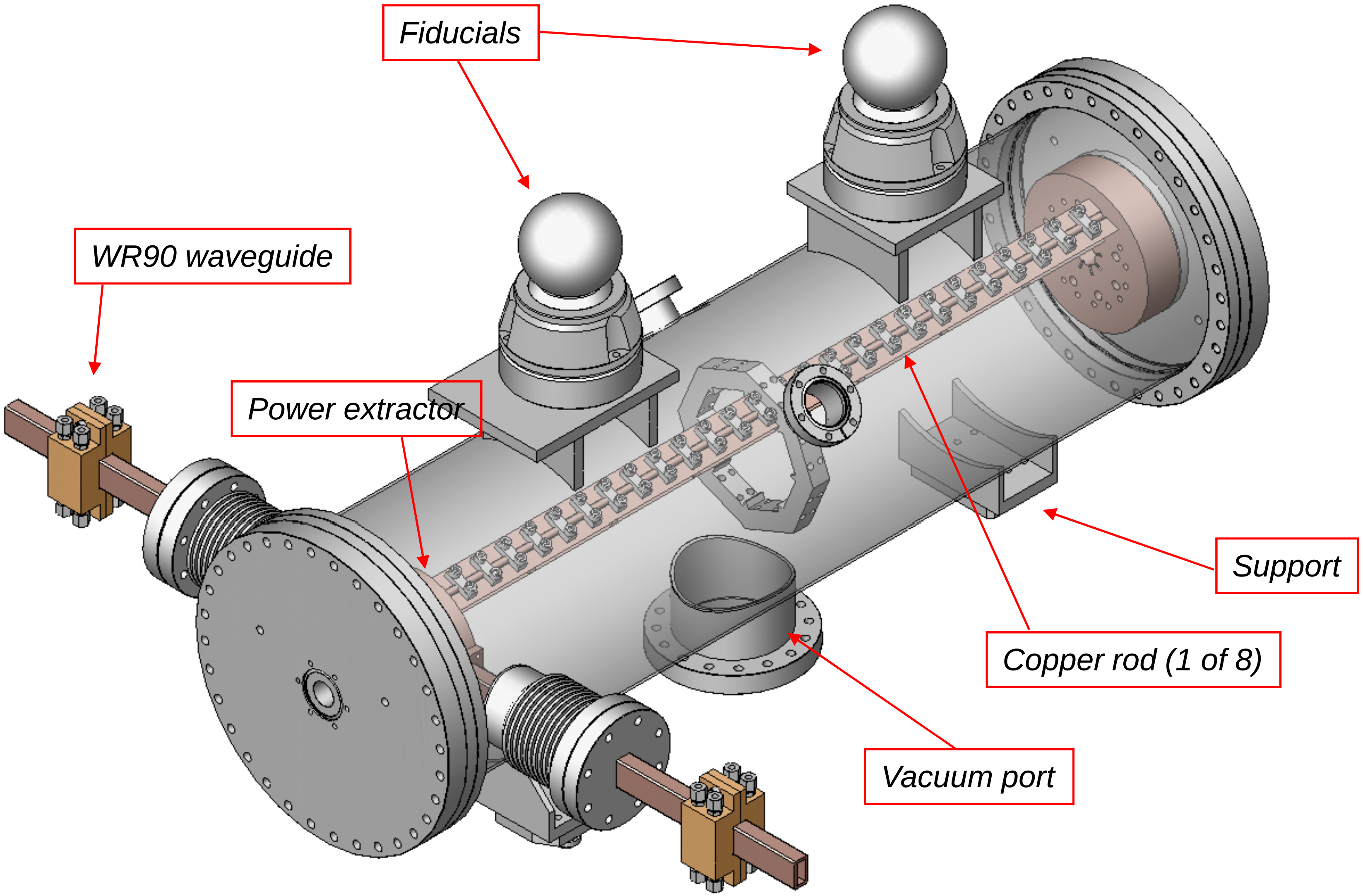
First TBL PETS prototype tank development



Courtesy N. Chritin, CERN

D. Carrillo, E. Rodríguez, F. Toral, CIEMAT
N. Chritin, S. Doebert, I. Syratchev, CERN
CERN, 24/01/2008

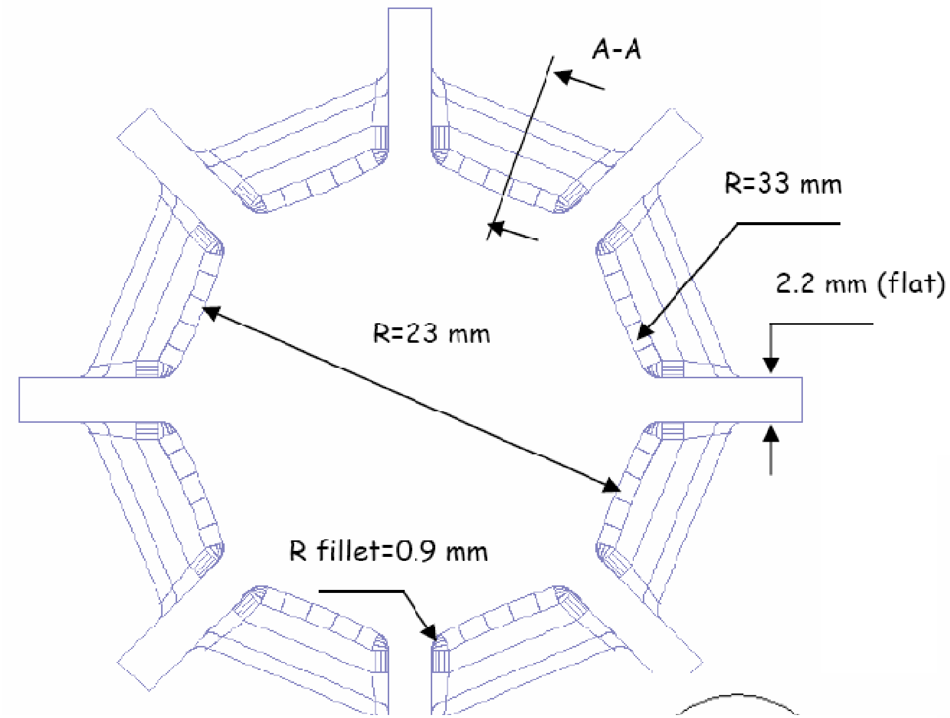
General layout



Outline

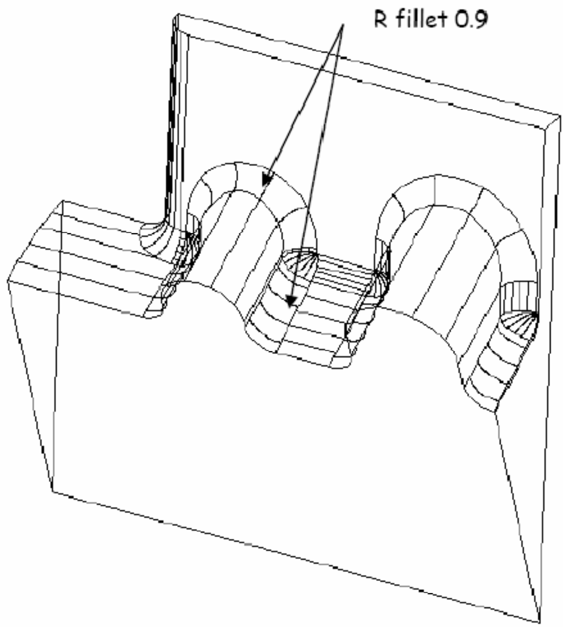
- ✓ Copper rods
- ✓ Measurement bench
- ✓ Power extractor
- ✓ Waveguides
- ✓ Cooling system
- ✓ Vacuum tank
- ✓ Assembly
- ✓ Near future schedule

Copper rods (I)

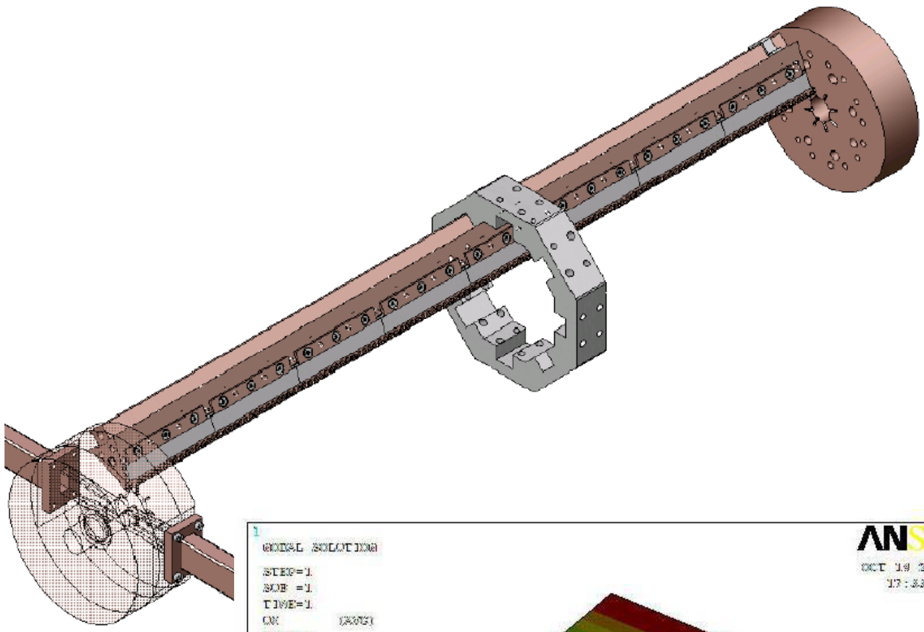


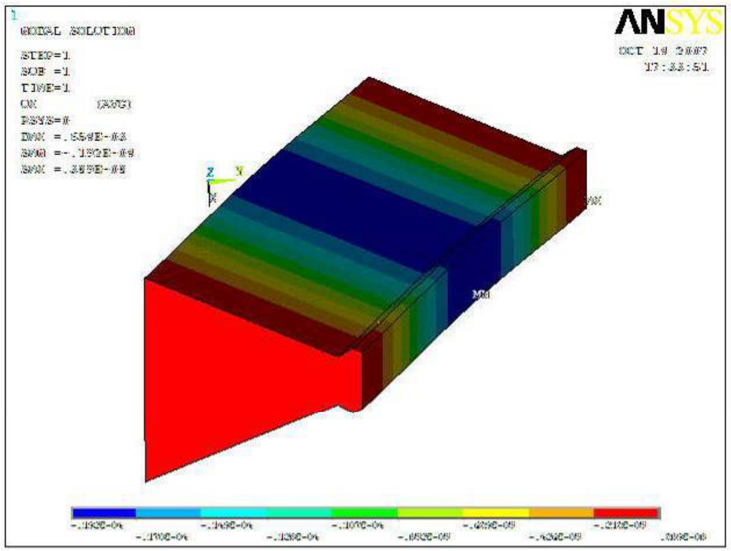
Courtesy I. Syratchev, CERN

- Geometry has been changed (June'07). Teeth are rounded.
- Advantages: lower peak field, shorter transition to circular aperture (matching cell).



Copper rods (II)

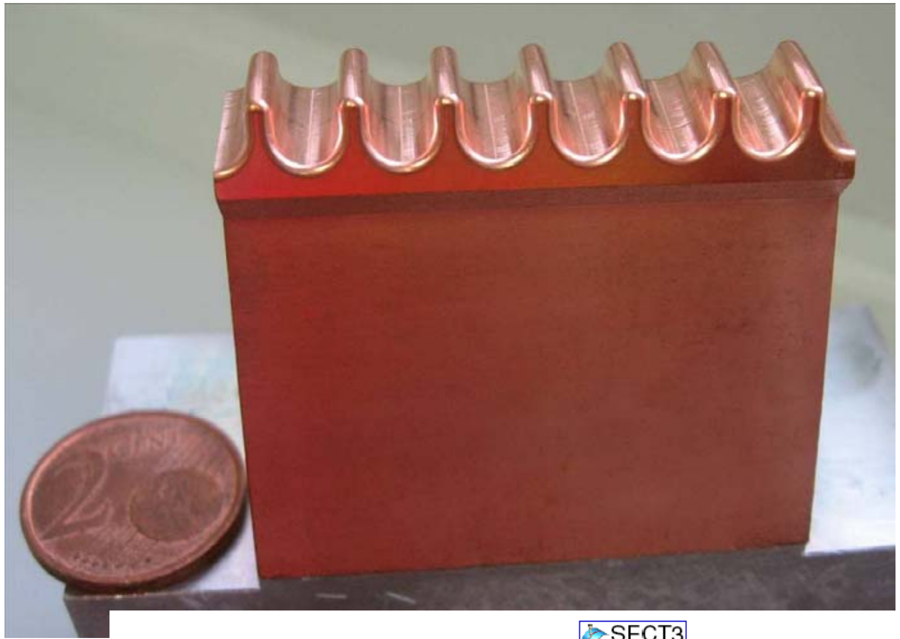


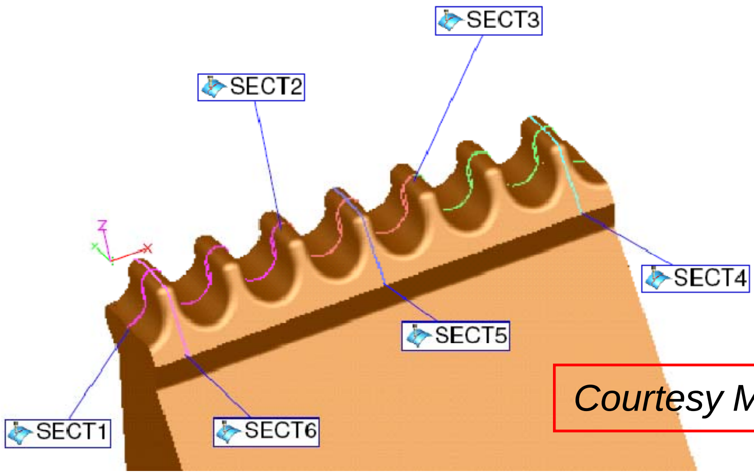


- End rings: two pins on each rod for alignment and one screw for clamping and enhancement of thermal contact.
- Intermediate stainless steel ring: the assembly is stiffer and sag is negligible. Besides, we correct small deformations due to internal stresses after machining. Two pins and two screws on each rod.

Height (mm)	Sag (micron)
35	29.3
40	23.4
45	19.2

Copper rods (III)



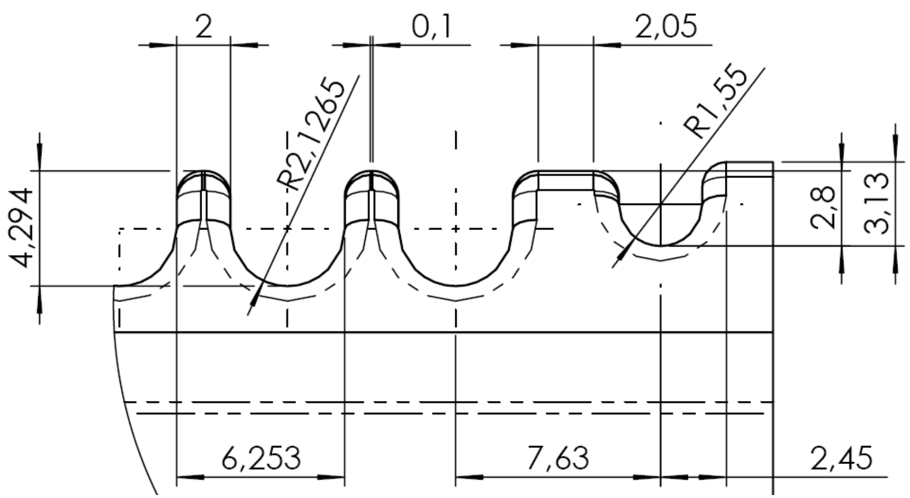


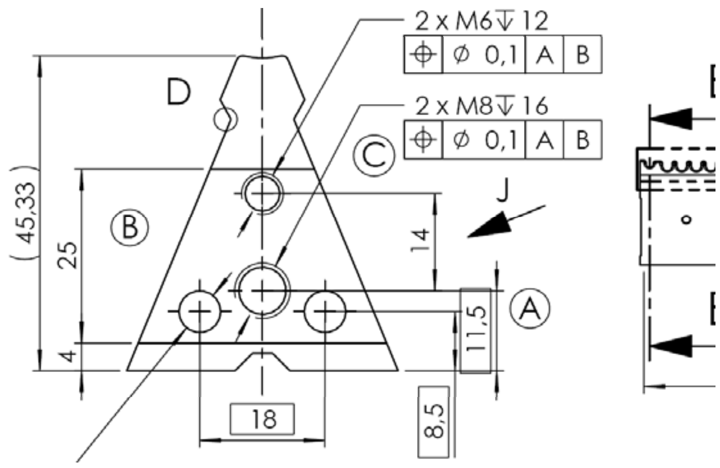
- Only one successful company (Utillajes Huerta, Madrid) from 4 candidates to machine a short probe (40 mm).
- It has been fully milled using sulphur-free coolants.
- Measured roughness (CERN) is 0.4 micron, in the order of the requested one, 0.3 micron (~skin depth 12 GHz).
- Requested geometrical tolerance is ±20 micron.

Courtesy M. Taborelli, CERN

Copper rods (IV)

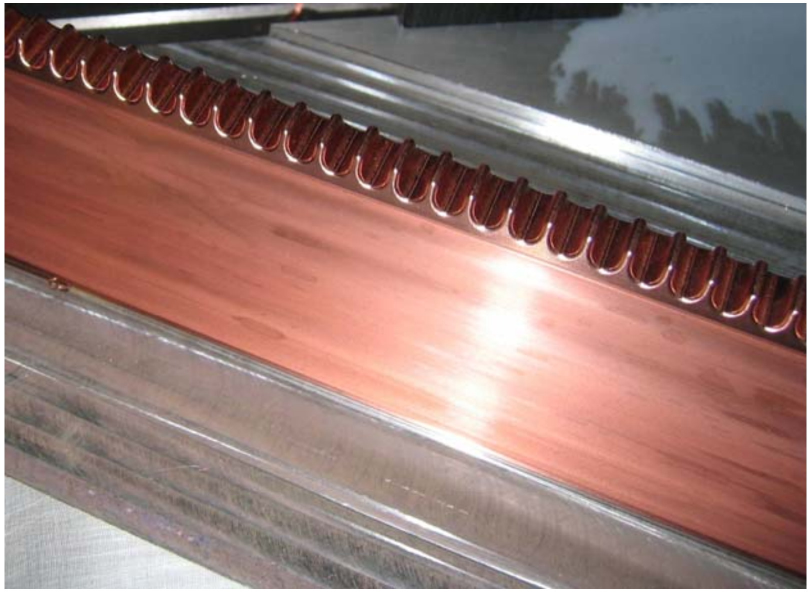
- The coupling cell wall was too thin (0.9 mm).
- As electrical contact is necessary, pressure must be made on that part of the rod.
- The rf power transmission is very sensitive to the coupling cell dimensions.
- A recess has been machined to enhance the contact on that edge.
- Power extractor has been recomputed (D. Carrillo): extractor geometry and rods to power extractor alignment are simpler now.

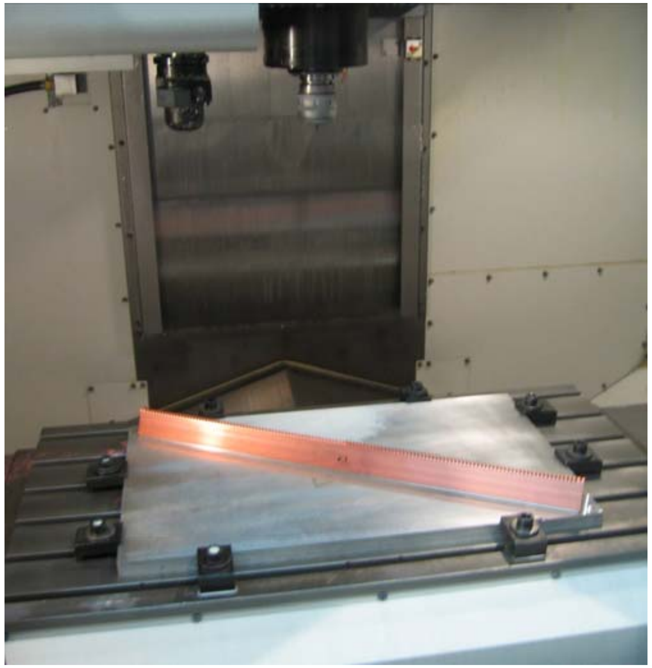




Copper rods (V)

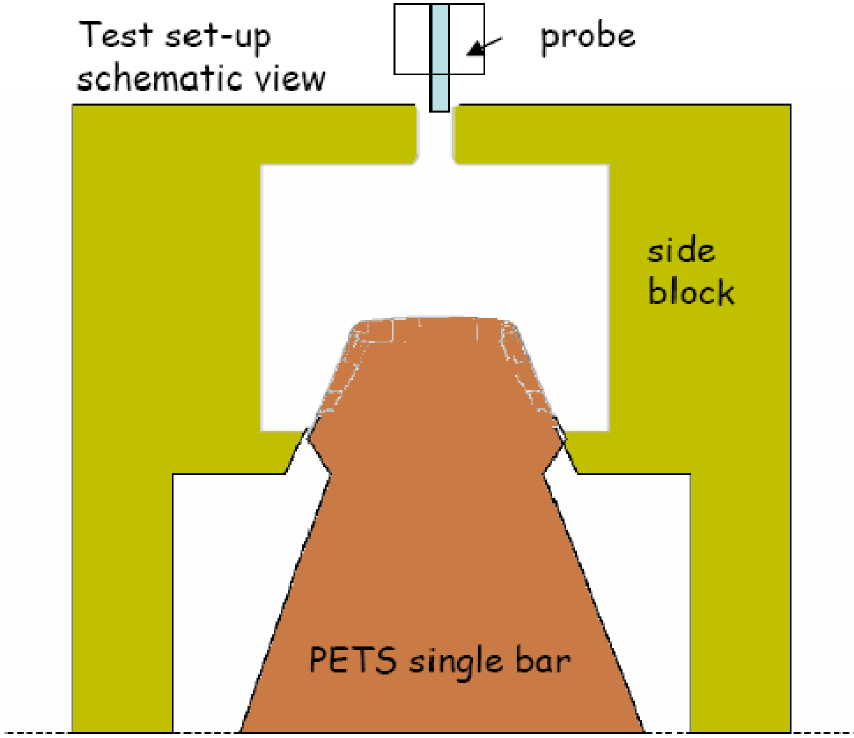
- First rod has been ordered to Huerta: 798.85 mm long
- Difficulties with the size of CNC program.
- Two intermediate thermal treatments to release internal stresses (1 hour at 180ºC).
- The rod is bolted to a plate not parallel to the machine axes.
- Dimension control with 3-D measurement machine.





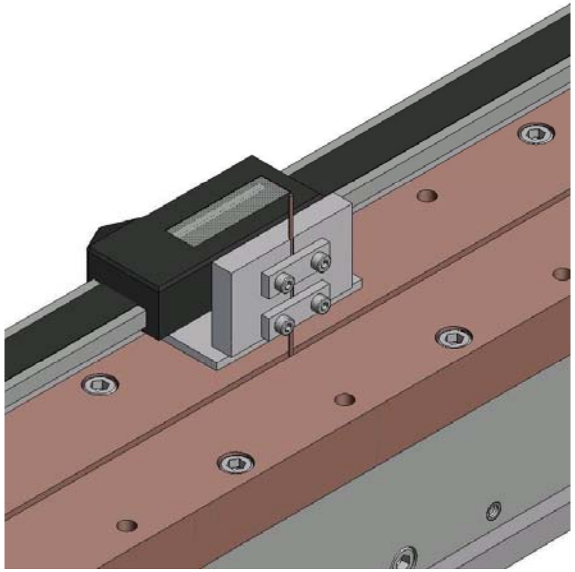
Single bar measurement bench (I)

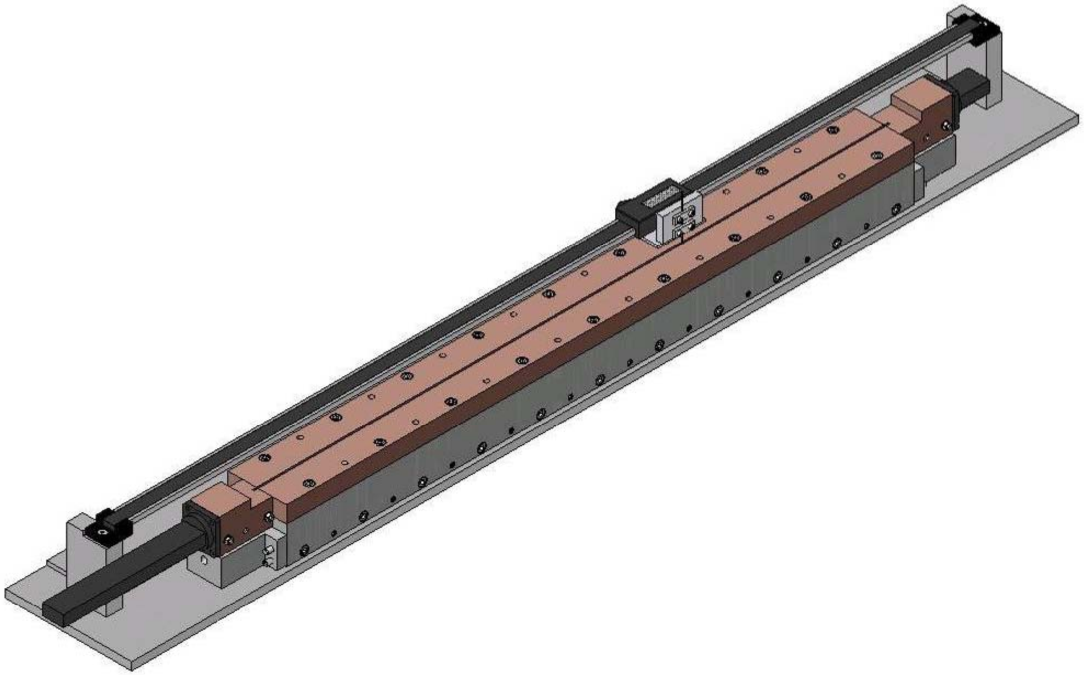
- A conceptual test bench for a single copper rod has been produced by Igor Syratchev (CERN).
- Detailed RF analysis and fabrication drawings by CIEMAT.



Single bar measurement bench (II)

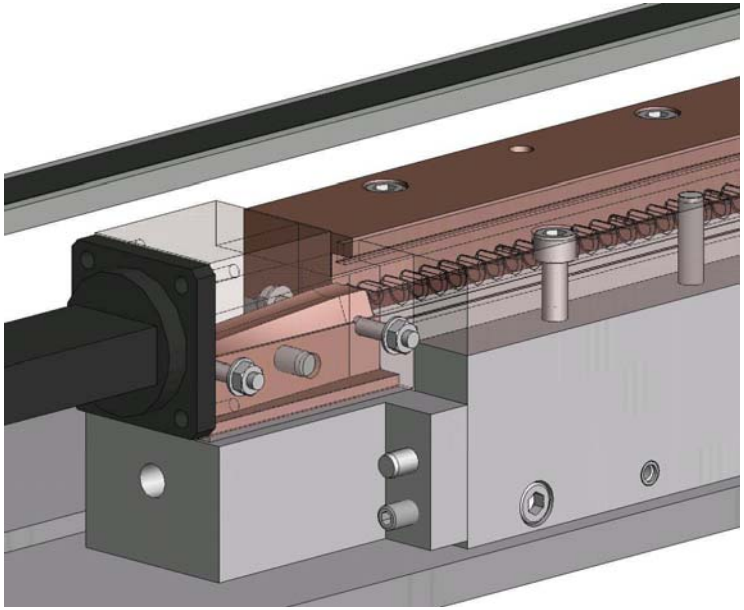
- The probe (a 1.2 mm diameter coaxial copper wire) is moved along a thin groove with an accurate 1 m long digital ruler.

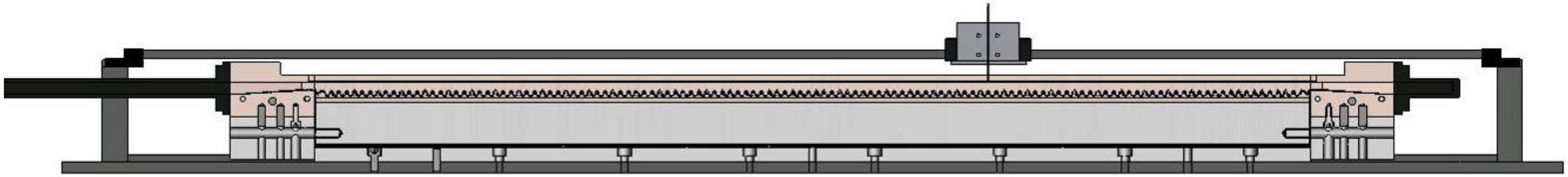




Single bar measurement bench (III)

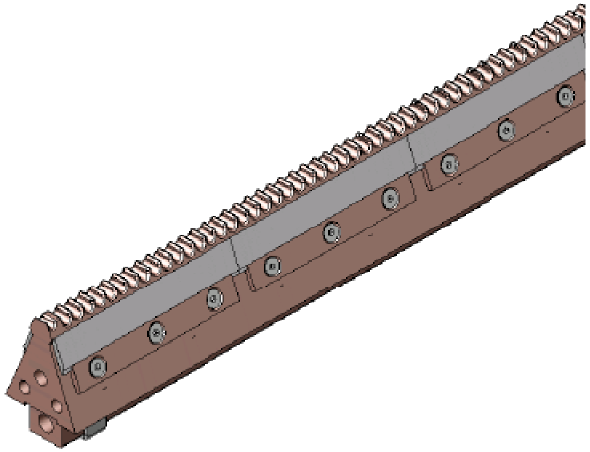
- A special input coupler has been designed.
- Special care is necessary to keep the electrical contact between different parts.
- Machining procedure is very important to guarantee the tight tolerances in such a long device.
- It will be ready for the end of January to test the first long copper rod.

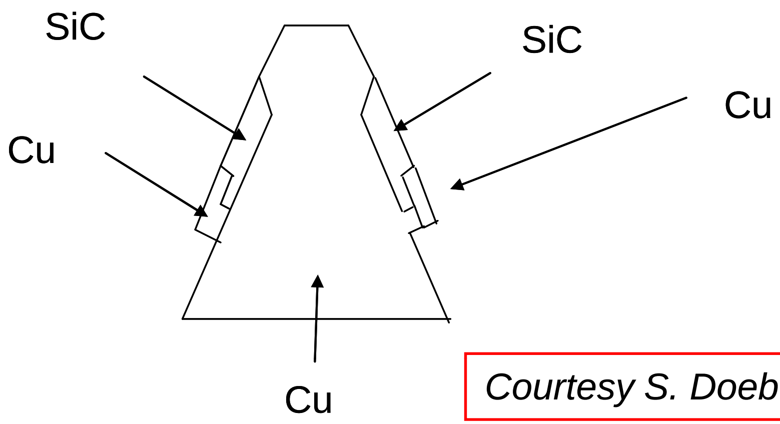




Absorbers

- RF absorbers for high order modes will be placed on both sides of the copper rods.
- They will consist of 100 mm long plates: 128 units are necessary.
- They will be clamped by auxiliary copper pieces and screws. To screw the absorbers directly is possible, but expensive.
- First attempt was done to use silicon carbide. We tested the one produced by Carbosystem (Spain) but it failed, because it is an electric conductor.
- Igor proposes an aluminium nitride composite produced by Ceradyne (US) as a better RF absorber in the range of frequencies of interest (14-16 GHz). Ceradyne could supply the absorbers (2-3 months delay).
- We have also contacted Sceram (France), which is able to machine complicated shapes on technical ceramics.

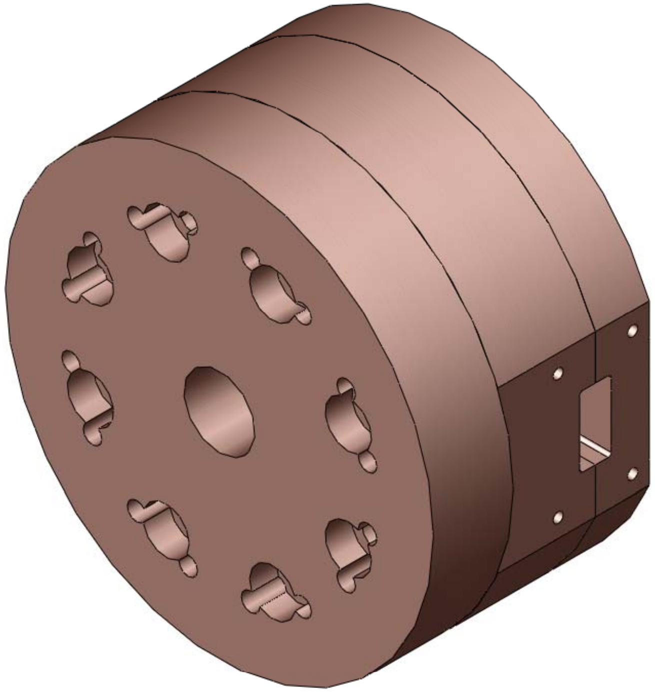


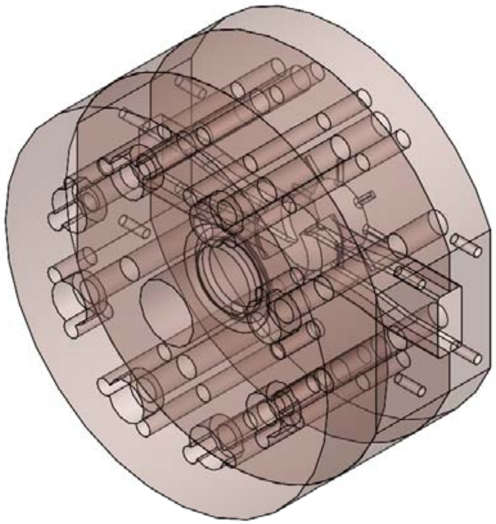


Courtesy S. Doebert, CERN

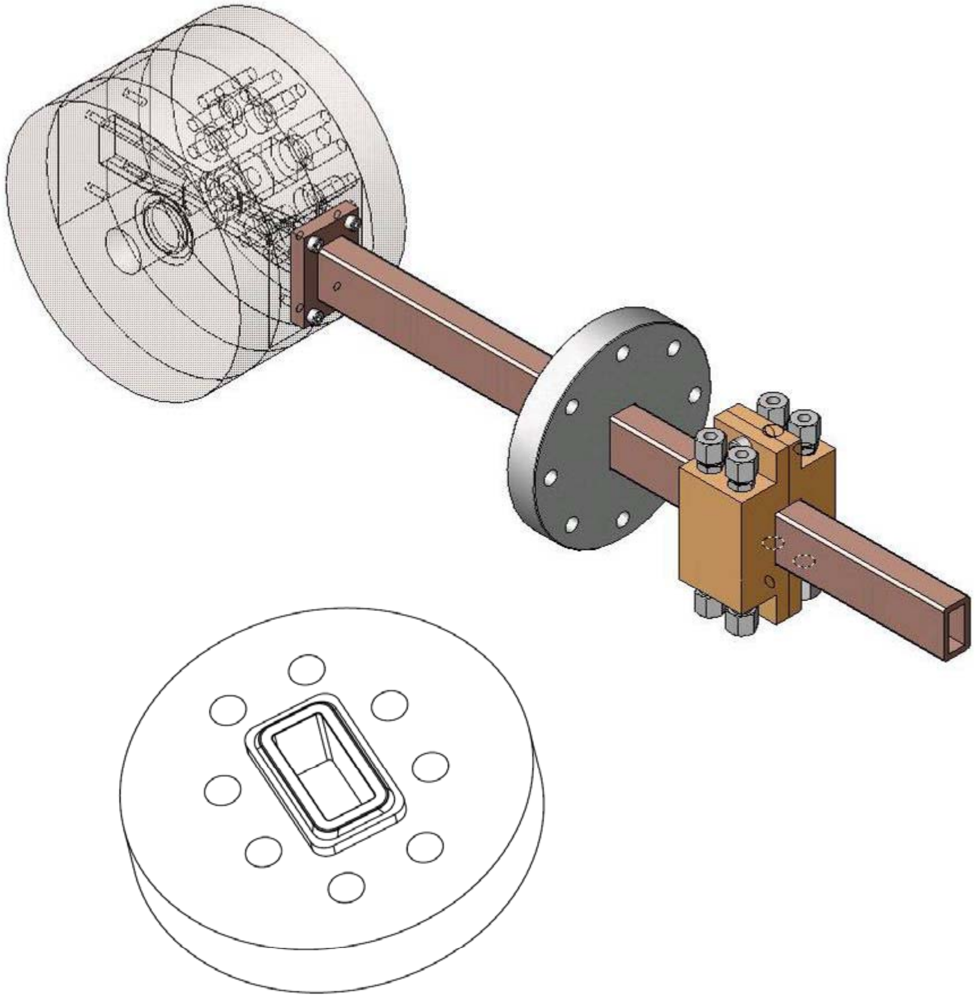
Power extractor

- Machined in three parts due to complicated geometry.
- Brazed to avoid virtual leaks and to get electric contact in the inner surface. It is important to avoid migration of brazing alloy into waveguide.
- Two configurations are possible: an intermediate gap or a zero-gap. Alloy can be placed as wire or sheet.
- We are evaluating both options. A zero gap with a 78Ag22Cu seems the most promising one.
- Holes will be machined after the brazing.



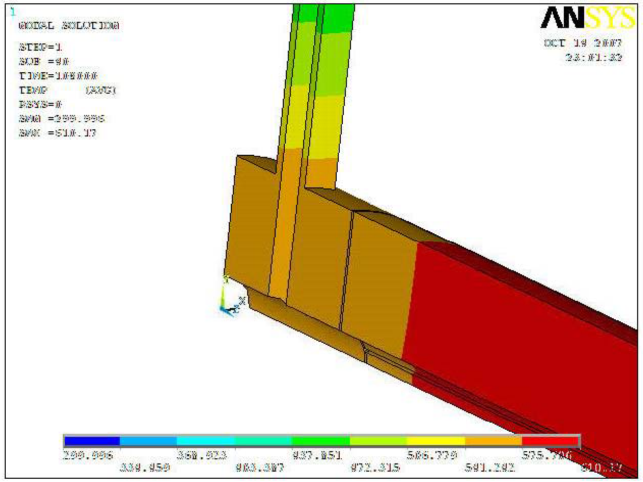


Waveguides



- Thick wall WR90 waveguides: 3.17mm.
- RF flange on the power extractor not defined yet. It should be custom designed. Large contact surface will decrease thermal resistance. It should be fixed once the copper set is inside the tank!
- A stainless steel vacuum flange should be brazed to the waveguide to close the tank.
- The external RF flange will be a SLAC-type one.

Thermal calculations (I)



- Steady state FEM: only conduction and natural convection. Thermal contact resistances are modelled with typical values from literature.
- Heating due to RF losses (imported from HFSS and averaged) and beam losses:

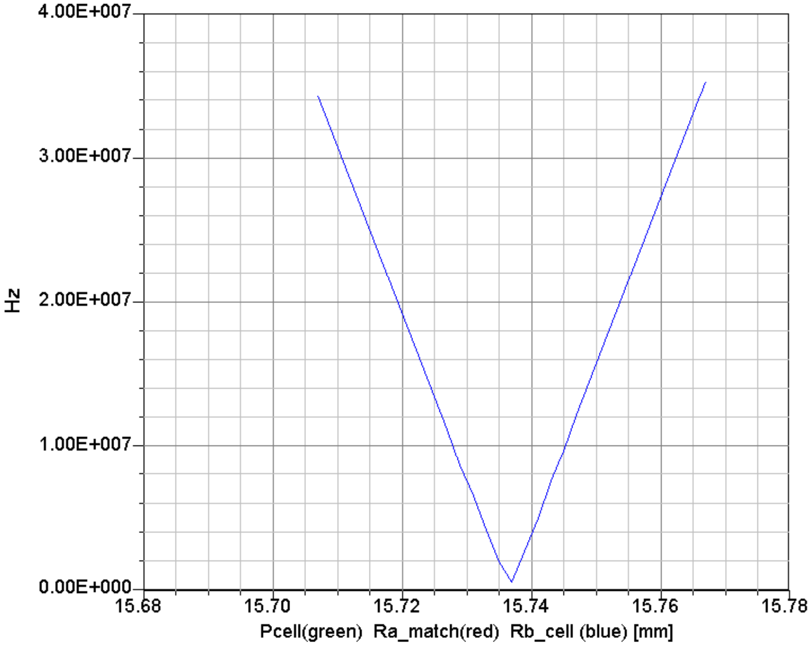
$$P_{beam\_losses} = 0.1 \times 150 MeV \times 30 A \times 140 ns \times 5 = 315 W$$

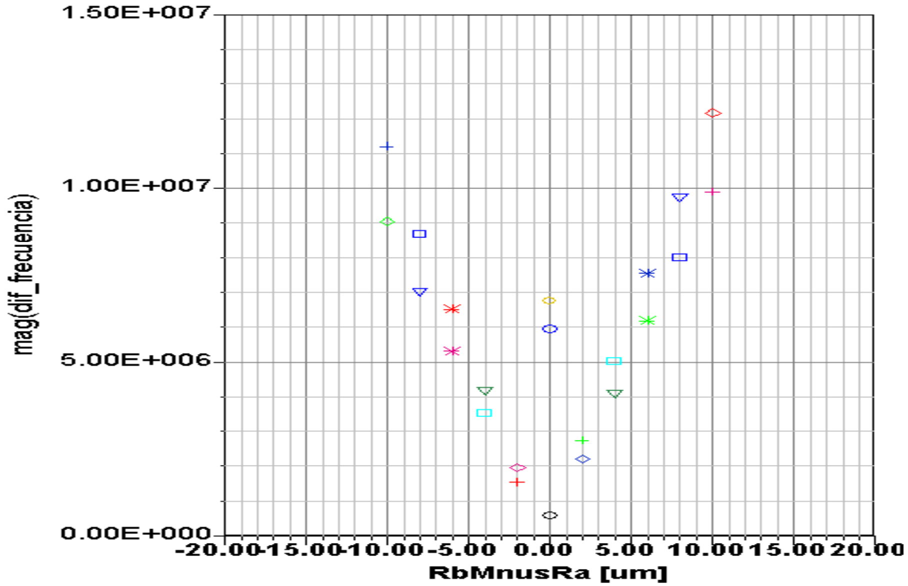
- In steady state:

Beam losses (%)	Peak temperature (K)
1	338
2	368
5	459
10	610

Thermal calculations (II)

- A temperature increase of 30ºC means a unitary elongation of $5*10^{-4}$, that is, about 8 micron for the PETS radius.
- RF sensitivity analysis shows a variation of few MHz.

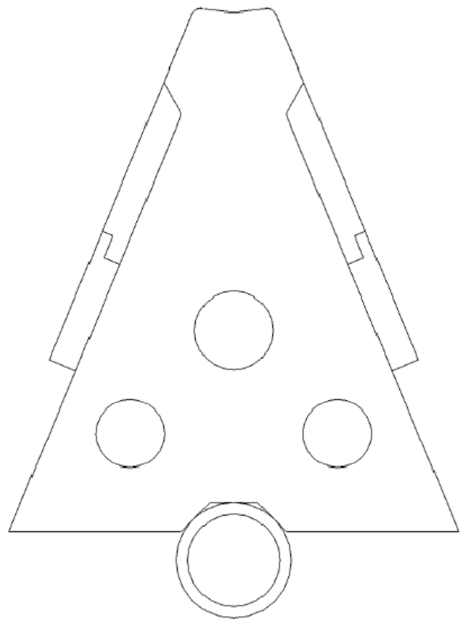




Courtesy of David Carrillo

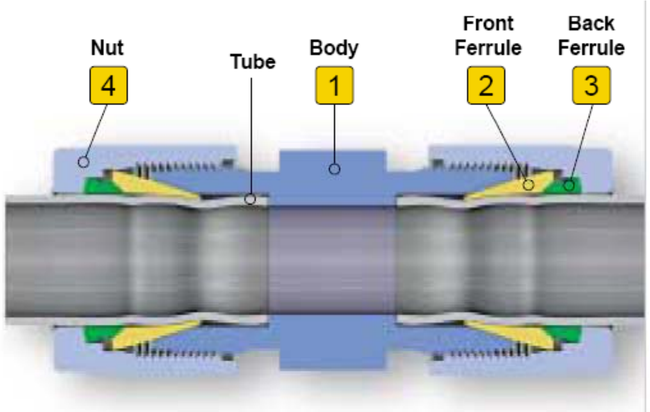
Cooling system (I)

- We think that round pipe is better than the square one to decrease thermal contact resistance.
- We think that ¼" copper pipe is fine.
- Rough calculations are made to get turbulent flow with a reasonable pressure drop:
  $v=1$ m/s $\Rightarrow Re=5100$
  $\Delta P=0.3$ bar (Darcy's equation)
- We assume $h=5000$ W/m^{2}K, 1/3 of the pipe inner surface to evacuate 37 W per rod: 2ºC temperature step from water to pipe.
- We assume $h=5000$ W/m^{2}K as equivalent thermal contact resistance, 3 mm long contact to evacuate 37 W per rod: 6ºC temperature step from pipe to rod.
- For two circuits (4 rods cooled by each one), water temperature increase is below 2ºC.



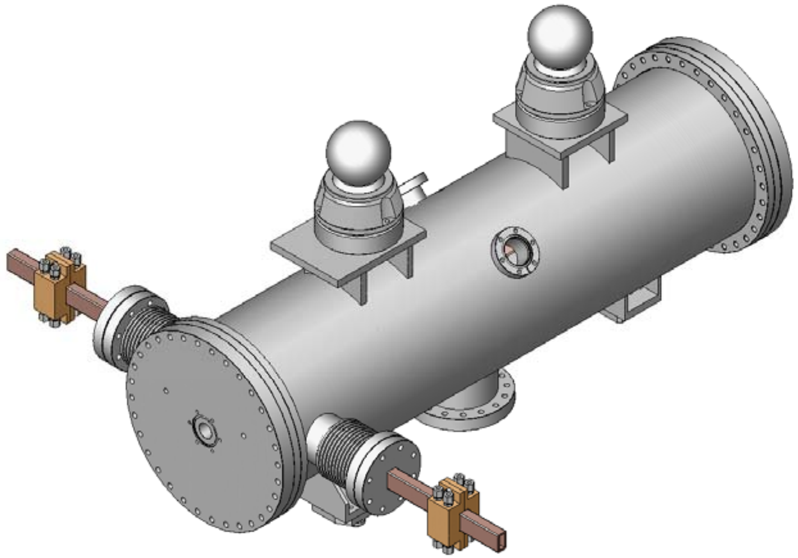
Cooling system (II)

- We have two choices for water connectors:
  - Based on double ferrule
  - Home made brazed connectors.
- We have welded some commercial connectors on a blank flange. We will test them in a vacuum tank.
- If we are not successful, we will do brazed connectors, which is a more expensive choice, but more reliable in a long-term basis.

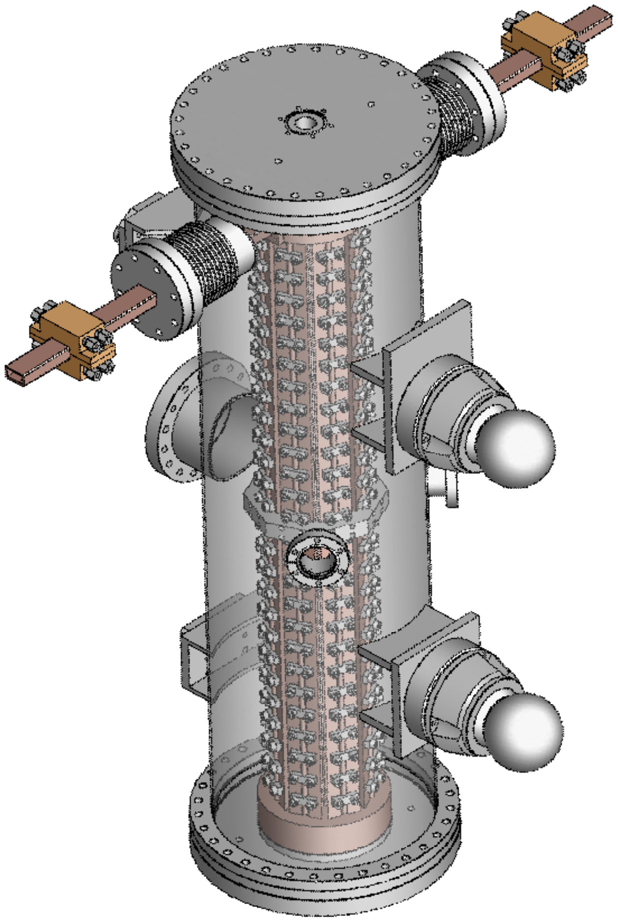


Vacuum tank

- Final length below 1 m: 986 mm
- 316LN flanges
- Auxiliary vacuum ports for instrumentation: temperature sensors
- Fiducials and supports according to CTF3 standards.
- As the inner parts are referenced to the endplates by pins, their position is directly transferred to the outer side, and available for alignment.
- Detailed design not finished yet: RF screens, below compression should be limited during pumping, RF waveguides support.



Assembly



- Vertical assembly of the copper rods on top of the solid copper end.
- Cooling circuit positioning.
- Stiffening steel ring and power extractor.
- Cooling circuit clamping.
- Tank wall.
- Waveguides (a special tool or an auxiliary flange will be necessary).
- The PETS axis reference is transferred outside by means of two pins drilled on the endplates.
- Last endplate to close the tank.

Near future schedule

- In the next two months:
  - Mechanical and RF measurements of the first long copper rod.
  - If it is valid, place the order for the 8 rods. If not, go for the second try.
  - Brazing tests for the power extractor.
  - Leak rate measurement of the commercial connectors.
  - RF characterization of the aluminium nitride composite absorbers from Ceradyne.
  - Finish the tank design.
- *We expect to finish the TBL PETS tank for June 2008.*